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WIND TUNNEL TESTS ON A MODEL OF A MONOPLANE WING WITH FLOATING AILERONS

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WIND TUNNEL TESTS ON A MODEL OF A MONOPLANE WING WITH FLOATING AILERONS.

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Summary

This report describes preliminary wind tunnel tests on a model of a monoplane wing equipped with wing tip floating ailerons. Lift and drag, as well as rolling and yawing moments, were measured. These tests are a part of a general research program on aerodynamic safety now in progress at the Langley Memorial Aeronautical Laboratory and were made in the Five-Foot Atmospheric Wind Tunnel.

The rolling moments were roughly independent of angle of attack and the yawing moments were small. With the ailerons neutral the minimum drag was more than twice that of the wing without ailerons. More suitable plan forms and profiles for wing and ailerons would probably give improved results.

Introduction

The preliminary tests described in this report were made to determine the lateral control effectiveness of wing tip floating ailerons with particular reference to the stalled flight condition. Data on the reduction of wing efficiency caused by such ailerons were also obtained.

It is generally recognized that the effectiveness of the conventional flap type of aileron is impaired when an airplane is stalled. The available rolling moment is considerably reduced, and in addition, the use of the ailerons produces a large yawing moment which acts against and may even exceed the rudder moment in a turn.

After much experimentation, the British have developed the Handley Page and Frise types of lateral control which appear to give improved controllability in stalled flight. In the United States comparatively little has been done on the study of this important problem. The present tests were among the first to be made under a general research program on aerodynamic safety which is being carried out at the Langley Memorial Aeronautical Laboratory in the Five-Foot Atmospheric Wind Tunnel (Reference 1).

While the idea of the floating aileron is not new, few tests have been made on the device (References 2 and 3) and it is understood that only one airplane using this type of control has been flown (Reference 4). Although the floating aileron appeared to possess certain disadvantages, it was deemed to be of sufficient technical interest to warrant its inclusion in the test program.

In principle this type of lateral control consists of a surface mounted in the vicinity of each wing tip and balanced both statically and aerodynamically about a lateral axis, so as to align itself with the relative wind when the control stick or wheel is in the neutral position. Operation of the lateral control turns one surface up and the other down with respect to the neutral position and a rolling moment is thus produced. If the interference effects between the wings and these surfaces be neglected, it will be seen that for a given lateral setting of the stick or wheel the rolling moment coefficient will be constant and the yawing moment will be zero for all angles of attack. However, the interference is not negligible and these conditions are only approximated as was indicated by the following test results, where the ailerons were mounted at the tips of a monoplane wing.

Apparatus and Tests

The wing model was a rectangular mahogany airfoil of 30-inch span, exclusive of ailerons, and 4.94-inch chord and had a symmetrical profile as shown in Figure 1, because the stability requirements of the floating ailerons could best be met by using an airfoil having a small center of pressure travel. The rectangular ailerons were of pine and each had a span of 4 in. and the same profile and chord as the wing. They were attached at the wing tips so as to form a continuation of the wing and the gap between wing and aileron was about .015 in. The axis of rotation was located on the chord line 1.16 in. (23.5 per cent chord) back from the leading edge. A steel rod running longitudinally through the wing in a slot connected the two ailerons which were a tight turning fit upon the rod. The rod and ailerons were statically balanced and were free to turn as a unit in small plain bearings mounted at each end of the wing. The displacement of the ailerons with respect to each other was accomplished merely by holding one and twisting the other on the rod to the desired angle, 2δ.

In Figure 2 the wing with ailerons is shown mounted in the tunnel on the rolling and yawing moment apparatus, and in Figure 3 this apparatus is shown in greater detail. The arm carrying the protractor extended through an opening in the tunnel wall in order that the angle of attack of the wing might be changed without shutting down the wind and entering the tunnel.

The tests were made at a dynamic pressure of 4.06 lb. per sq.ft., corresponding to an air speed of about 40 m.p.h., or a Reynolds Number of about 148,000. They covered an angle of attack range from -2° to 35° and aileron displacement angles $\delta = 0$, $\pm 5^\circ$, $\pm 10^\circ$, $\pm 15^\circ$, and $\pm 20^\circ$. For $\delta = \pm 20^\circ$, when the angle of attack was brought below 15°, the ailerons oscillated with sufficient violence to prevent reading of the balances.

There were three groups of tests in which the following measurements were made:

1. Rolling and yawing moments.
2. Lift and drag.
3. Mean floating angle of ailerons.

The rolling and yawing moments were measured on the apparatus described above. The net moments were taken as one-half the difference between the gross readings for the ailerons turned first in one direction and then the other with respect to the wing, in order to eliminate, as far as possible, the effects of asymmetry in the apparatus and air flow. This method was possible, since the variations in the static tare readings during a run were within the experimental error.

The lift and drag tests were made on the regular wire balance.

The angles between the wind direction and the mean position of the floating ailerons were determined with the model mounted on the force test wire balance. A line was drawn on the end of one aileron and a straight-edge carrying a bubble inclinometer mounted outside the tunnel was used to sight on this reference line through an opening in the tunnel wall.

Since the tests were intended to be preliminary in nature, great precision was not attempted. The probable error in the measurement of rolling and yawing moments was ±3 per cent, while for the lift and drag it was, in general, within ±2 per cent. The angle of attack and the aileron displacement angles were accurate to within ±.25° and the floating angle could be measured to within ±.3°. In construction of the wing the ordinate tolerance was ±.006 in.

Results

The results of the rolling and yawing moment tests are presented in Table I and Figures 4 and 5, in the form of absolute coefficients.

$$C_L' = \frac{L'}{qbS}$$

and $$C_N = \frac{N}{qbS}$$

where C_L' = rolling moment coefficient.

C_N = yawing moment coefficient.

L' = measured rolling moment.

N = measured yawing moment.

q = dynamic pressure.

b = span of wing proper (minus ailerons).

S = area of wing proper (minus ailerons).

The force test results are given in Table II and Figures 6, 7, 8 and 9, in the form of the customary absolute coefficients of lift C_L, and drag C_D. These coefficients also are calculated on the basis of the area of the wing proper (minus ailerons).

In Figure 10 the mean floating angle of the ailerons is given for various aileron settings and angles of attack

Discussion

The results of the rolling and yawing moment tests as shown in Figures 4 and 5 indicate that the rolling moment is roughly uniform for a given aileron displacement, except for limited regions near 16° and 35° angle of attack where, however, the reduction in rolling moment is only about 30 per cent for the ailerons set at ±15°. Also, the yawing moments are relatively small and are even negative at the larger angles of attack. The fact that the rolling moment is not exactly constant and the yawing moment is not zero, is due to flow interference effects between the aileron and the wing tip as mentioned hitherto. Figures 6 and 7 indicate that the drag due to the neutral ailerons at zero angle of attack is almost double that for the wing without ailerons. This is a serious limitation from the standpoint of aerodynamic efficiency.

During the tests it was noticed that for both zero and 5° aileron displacements there were two positions at which the ailerons would float. In Figures 8 and 9 are given the lift and drag curves for this peculiar condition. It will be seen that the upward aileron position is stable for a smaller angle of attack range than the downward. For larger aileron displacements this dual balance characteristic disappears.

If the wing were removed from between the two symmetrical profile ailerons, it is apparent that their mean floating angle of attack would be zero for any displacement relative to each other. The presence of the wing, however, materially alters the flow, and Figure 10 is an indication of this alteration. In this figure the angle between the mean position of the ailerons and the air stream is plotted against the angle of attack of the wing. The wing tip vortices are probably responsible for the negative floating angle of attack of the ailerons. In the vicinity of zero lift $(\alpha = 0)$ where the vortices are of small magnitude, it might be expected that the ailerons when neutral would coincide with the wing. Actually, however, an unstable condition was noted and the neutral ailerons assumed floating angles of $+16^\circ$ or -16°, as mentioned above. This condition is shown in Figure 10 for negative floating angles only since the airfoil profile used was symmetrical. The same tendency existed for $\delta = \pm 5^\circ$, but disappeared for larger aileron displacements and for angles of attack above 5°.

The results of these tests indicate that the desired lateral control characteristics, i.e., constant rolling moment and zero yawing moment coefficients can be approximated for a monoplane wing by using the floating wing-tip type of aileron. The tests also show that the price paid for this improved controllability is in the form of reduced wing efficiency. In addition, such a device will probably have somewhat greater weight and complexity than the conventional aileron type of control.

However, in justice to the floating aileron, it may be stated that the rudimentary design of the model used in these tests was not favorable to the best results. The symmetrical airfoil section had a rather sharply peaked lift curve which probably accounts for the abrupt decceases in rolling and yawing moments in the vicinity of the angle of maximum lift as shown in Figure 4. Moreover, the rectangular form of both wing and ailerons produced high tip loads and large downwash angles at the tips which probably were largely responsible for aileron instability and the large interferences. Improvements in the efficiency and uniformity of operation of such ailerons may be expected if care is taken to reduce interference of the flows around wing and ailerons, and this may be done in large measure by a judicious shaping of the ends of both wing and ailerons.

Conclusions

1. The wing tip floating ailerons as tested produced rolling moments that were roughly independent of angle of attack except near the angle of maximum lift where, however, the reduction was not great.

2. The yawing moments were relatively small in all cases and were negative at the larger angles of attack.

3. The minimum drag of the wing with ailerons neutral was

more than twice that of the wing without ailerons.

4. Reduction of interferences between wing tip and aileron by the use of more suitable plan forms and profiles may improve the rather erratic behavior of the floating ailerons as evidenced in these tests, and may also increase the efficiency of the combination.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 16, 1929.

References

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2. Bradfield, F. B. and Simmonds, O. E. : Rolling and Yawing Moments Due to Roll of Model Avro Wings with Standard and Interplane Ailerons and Rudder Moments for Standard and Special Large Rudder. British Aeronautical Research Committee Reports and Memoranda No. 848 (1922).
3. Bradfield, F. B. and Peatfield, I. L. : Lateral Control at Low Speeds. British Aeroanutical Research Committee Reports and Memoranda No. 717 (1920).
4. Hill, Captain G. T. R. : The Tailless Aeroplane. Journal of the Royal Aeronautical Society, No. 189 (September, 1926).

TABLE I.

Rolling and Yawing Moment Coefficients

Reynolds Number = 148,000 - q = 4.06 lb.-per sq.ft. -

Degrees	δ = ±5°		δ = ±10°		δ = ±15°		δ = ±20°	
	C_L'	C_N	C_L'	C_N	C_L'	C_N	C_L'	C_N
0	.0358	.0115	.0721	.0049	.1060	.0015	–	–
5	.0391	.0122	.0734	.0091	.1098	.0074	–	–
10	.0388	.0119	.0705	.0108	.1030	.0081	–	–
12	.0378	.0105	.0687	.0108	.0998	.0064	–	–
14	.0346	.0078	.0634	.0067	–	–	–	–
15	.0330	.0034	.0549	.0035	.0730	.0055	.0952	.0051
17	.0202	.0035	.0485	.0055	.0751	.0088	.1033	.0050
18	.0321	.0033	.0626	.0062	.0770	.0100	.1006	.0107
20	.0359	.0018	.0689	.0040	.0958	.0070	.1177	.0091
22	–	–	–	–	.0950	.0056	–	–
25	.0370	-.0002	.0671	.0011	.0926	.0040	.1160	.0066
30	.0348	-.0024	.0620	-.0018	.0873	.0006	.1097	.0031
35	.0278	-.0042	.0529	-.0059	.0778	-.0030	.1011	-.0009

TABLE II.

Lift and Drag Coefficients

Reynolds Number = 148,000 q = 4.06 lb. per sq.ft.

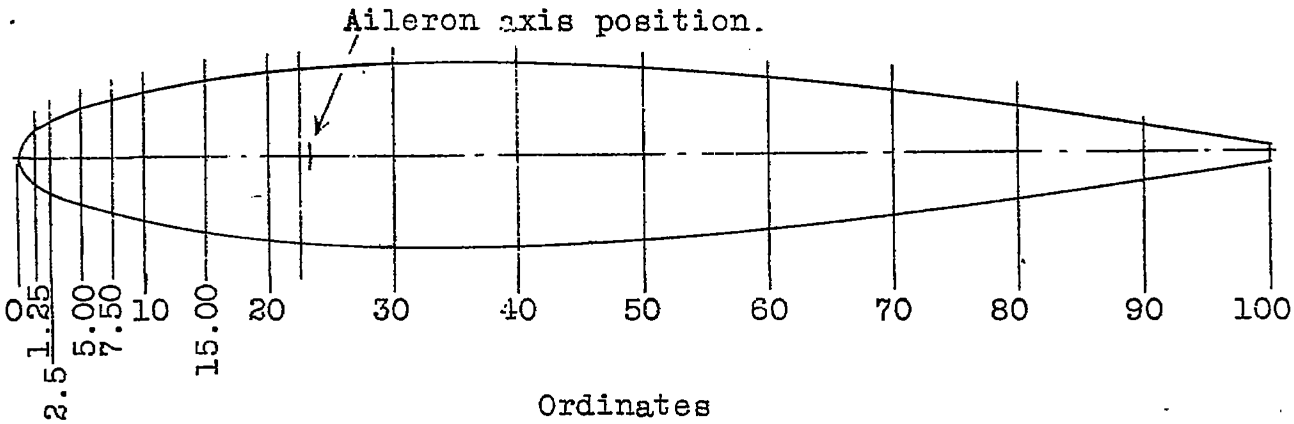
Degrees		No ailerons		δ = 0°		δ = ±5°	
		C_L	C_D	C_L	C_D	C_L	C_D
Ailerons Down	-2°	-.143	.017	-.356	.047	-.396	.048
	0°	+.015	.015	-.200	.040	-.227	.047
	2°	.168	.016	-.026	.043	-.051	.052
	5°	.422	.027	.269	.054	+.244	.061
	10°	.745	.057	.699	.084	.669	.088
	11°	.778	.066	.752	.092	.746	.094
	12°	.841	.078	.788	.102	.787	.101
	13°	.773	.126	.755	.144	.747	.149
	14°	.737	.159	.712	.179	.729	.180
	15°	.629	.206	.585	.225	.628	.224
	17°	.591	.244	.543	.260	.605	.260
	18°	.590	.262	.553	.278	.604	.278
	19°	.588	.279	.643	.288	.602	.294
	20°	.600	.295	.648	.302	.604	.315
	25°	.621	.376	.678	.401	.639	.394
	30°	.686	.492	.752	.518	.723	.515
	35°	.755	.622	.763	.616	.746	.634
Ailerons Up	-5°	Unstable		-.235	.050	-.216	.058
	-2°			+.062	.040	+.071	.048
	0°			.240	.037	.239	.045
	+2°			.397	.036	.401	.043
	+5°			.680	.042	.674	.044

TABLE II (Cont.)

Lift and Drag Coefficients

Reynolds Number = 148,000 q = 4.06 lb. per sq.ft.

	Degrees	δ = ±10°		δ = ±15°		δ = ±20°	
		C_L	C_D	C_L	C_D	C_L	C_D
Ailerons Down	-2°	-.173	.033	-.214	.045	–	–
	0°	-.011	.031	-.047	.044	–	–
	2°	+.144	.033	+.139	.046	–	–
	5°	.392	.045	.400	.060	–	–
	10°	.743	.083	.725	.096	– Unstable	–
	11°	.777	.093	.748	.107	–	–
	12°	.795	.102	.789	.118	–	–
	13°	.780	.157	.755	.179	–	–
	14°	.743	.184	.695	.205	–	–
	15°	.639	.234	.646	.249	.595	.280
	17°	.570	.271	.597	.288	.559	.315
	18°	.577	.288	.576	.309	.558	.337
	19°	.568	.305	.567	.327	.567	.353
	20°	.578	.320	.572	.343	.566	.369
	25°	.623	.413	.620	.430	.613	.455
	30°	.694	.530	.688	.540	.684	.566
	35°	.734	.644	.720	.656	.721	.676
Ailerons Up	-5°						
	-2°						
	0°			Unstable			
	+2°						
	+5°						



Ordinates

% from lead. edge	% of chord Upper	Lower
0	0.00	0.00
1.25	2.08	2.08
2.5	2.94	2.94
5.0	4.00	4.00
7.5	4.76	4.76
10.0	5.36	5.36
15	6.33	6.33
20	6.90	6.90
30	7.51	7.51
40	7.58	7.58
50	7.14	7.14
60	6.30	6.30
70	5.06	5.06
80	3.80	3.80
90	2.33	2.33
100	0.80	0.80

Axis of ailerons 23.5% from leading edge.

Fig.1 Symmetrical airfoil profile.

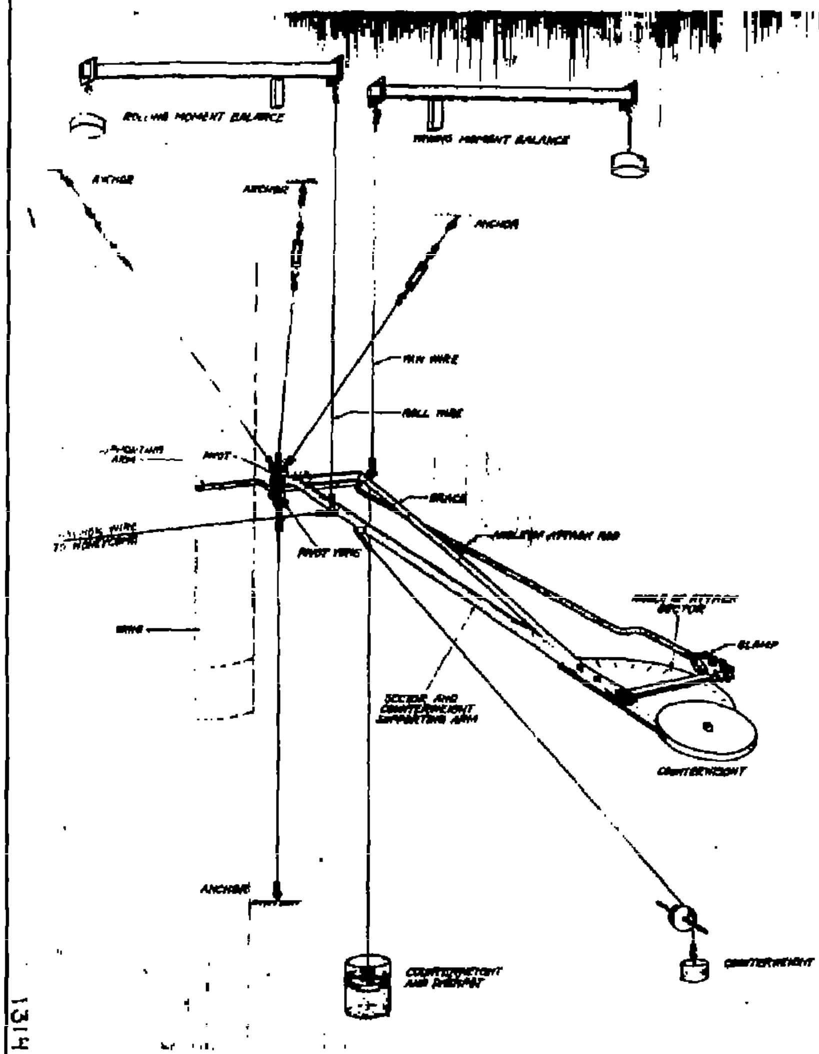


Fig.3 Diagram of rolling and yawing moment set-up.

Fig.2 Wing model with floating aileron mounted in wind tunnel.

1314 8.A.S

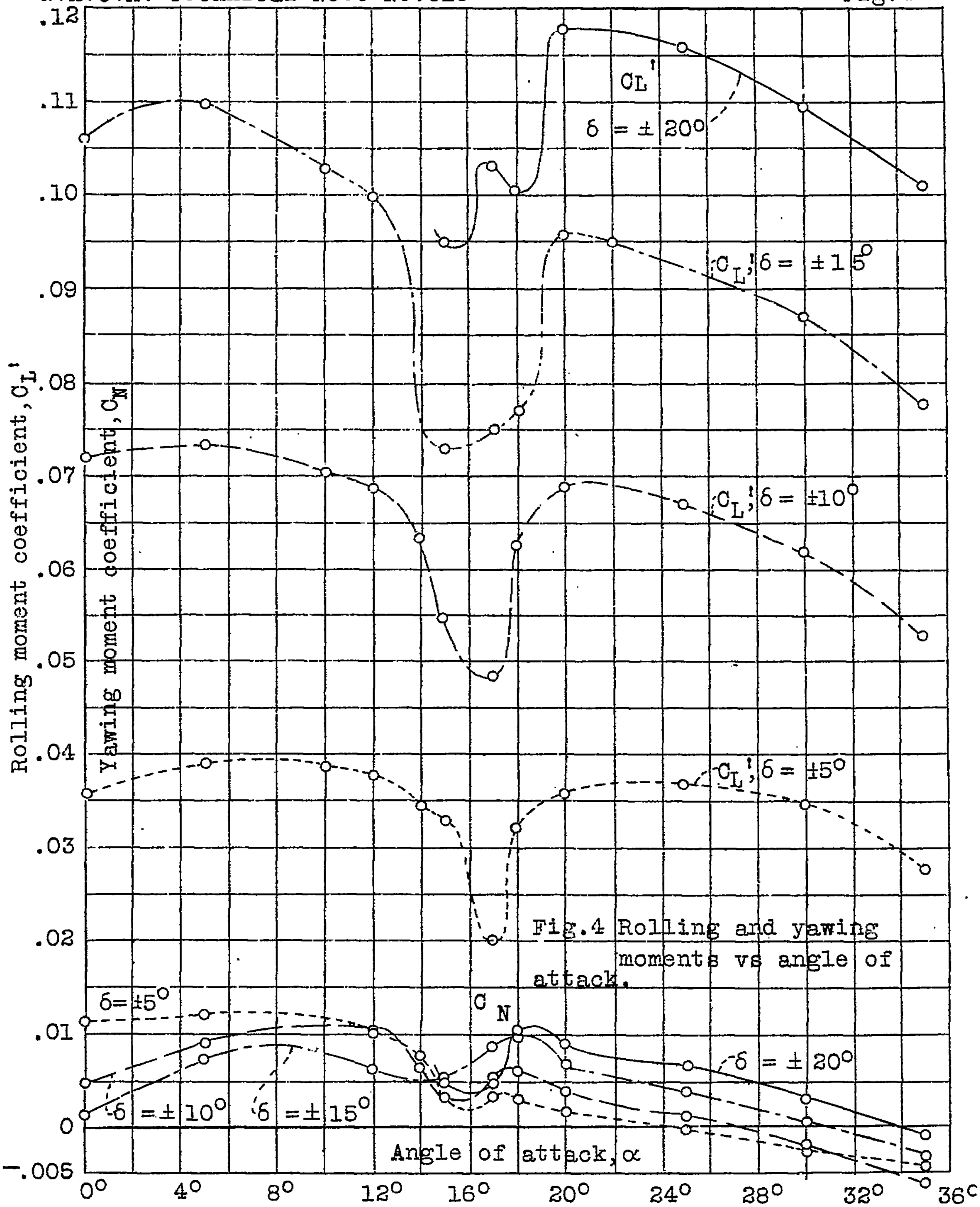


Fig.4 Rolling and yawing moments vs angle of attack.

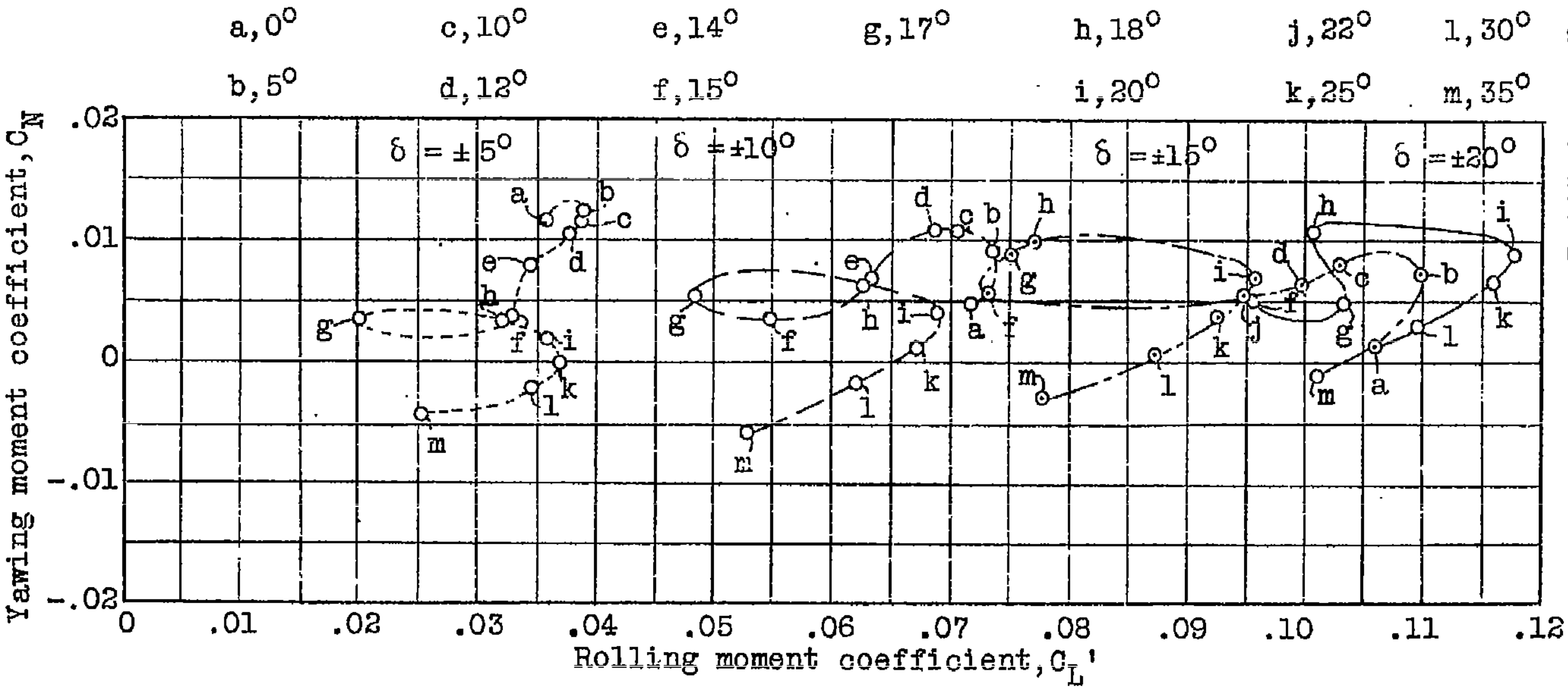


Fig.5 Moment vectors.

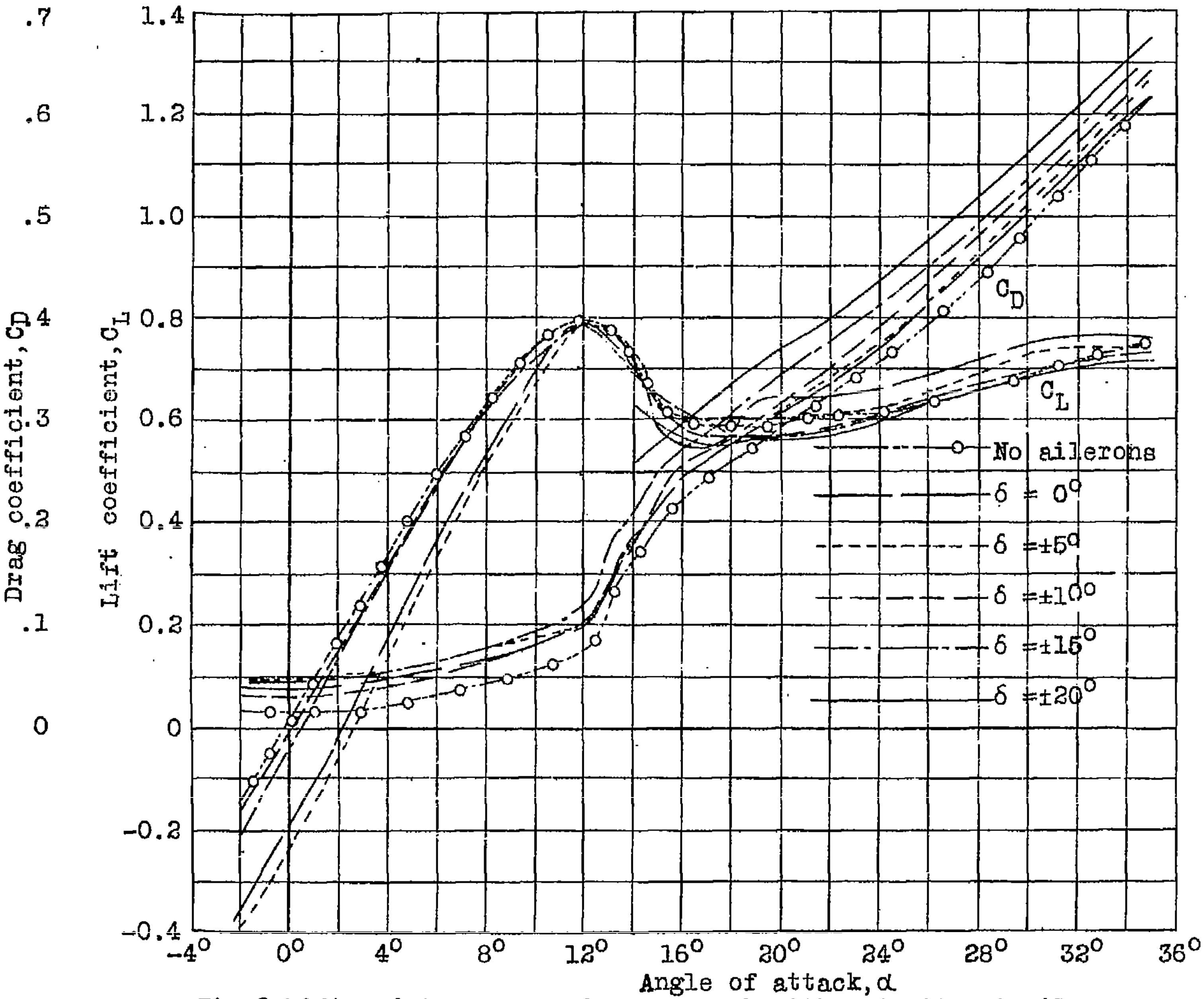


Fig.6 Lift and drag vs angle of attack with and without ailerons.

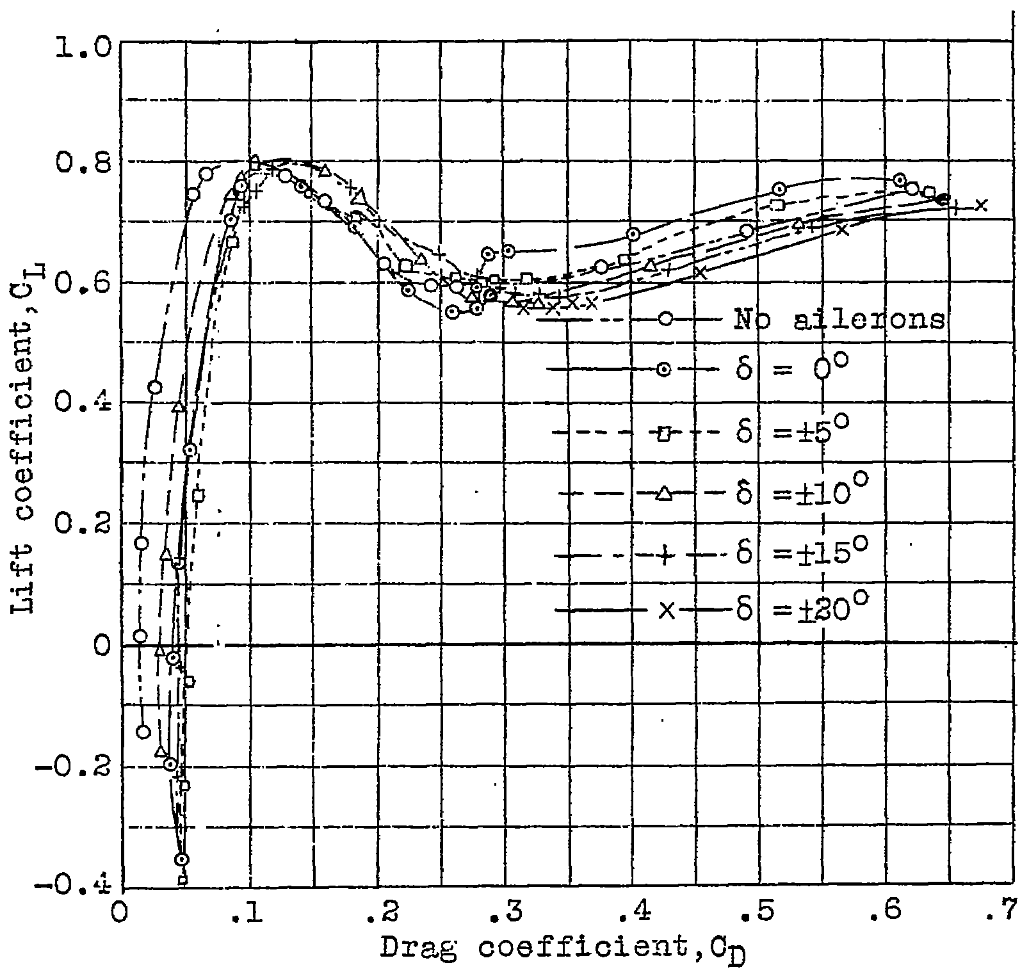


Fig.7 Force polars with and without ailerons.

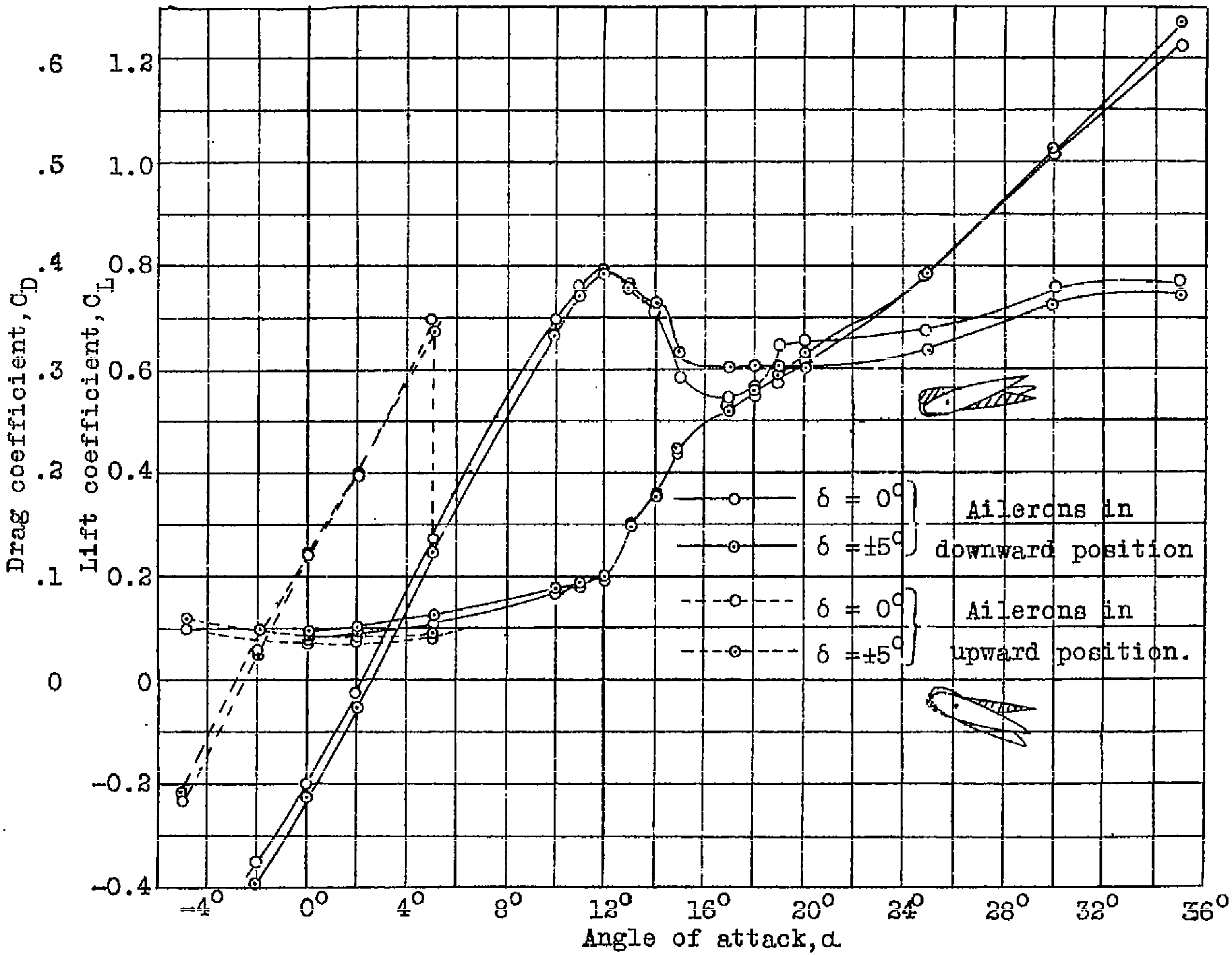


Fig.8 Lift and drag vs angle of attack. Aileron setting with two stable positions.

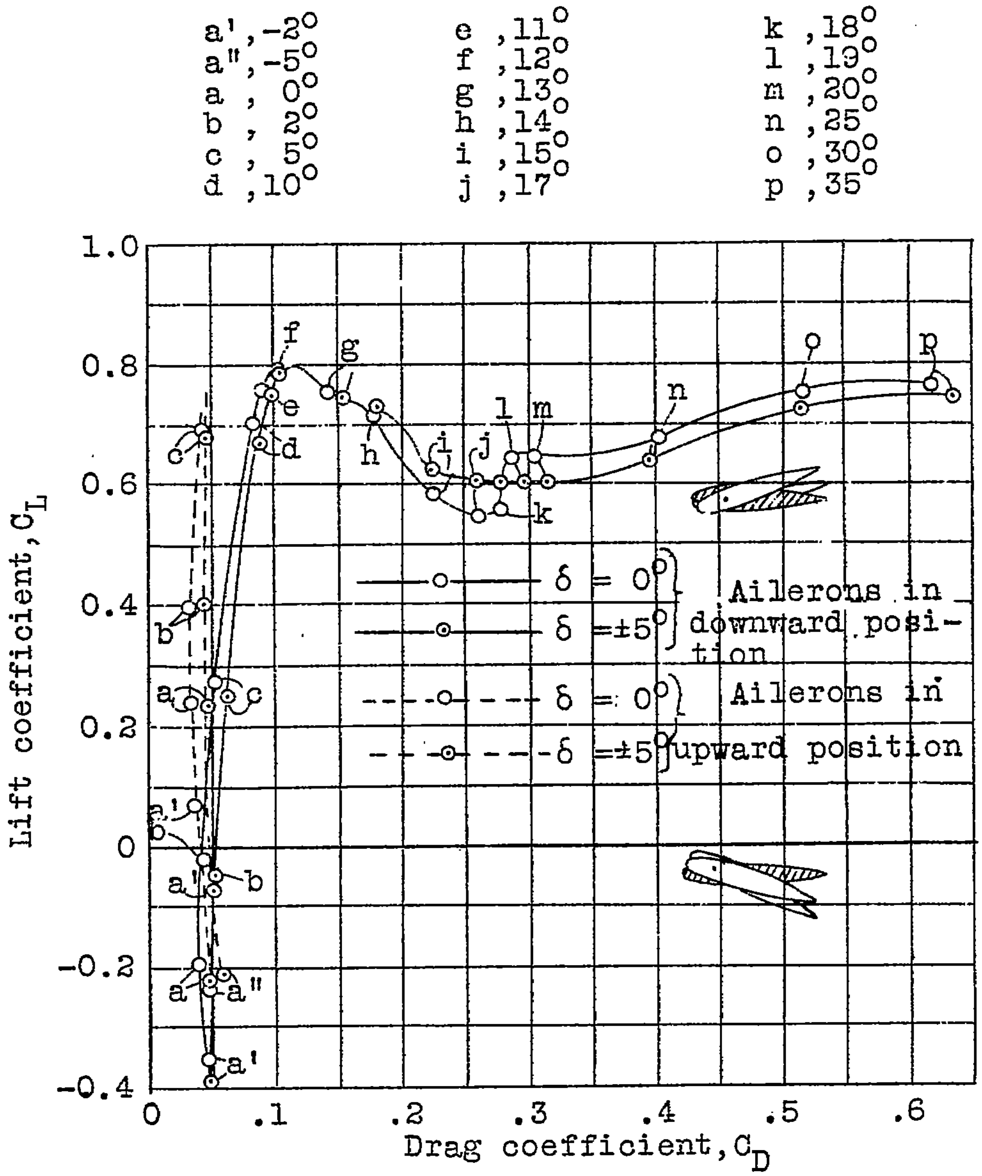


Fig.9 Force polars, ailerons setting with two stable positions.

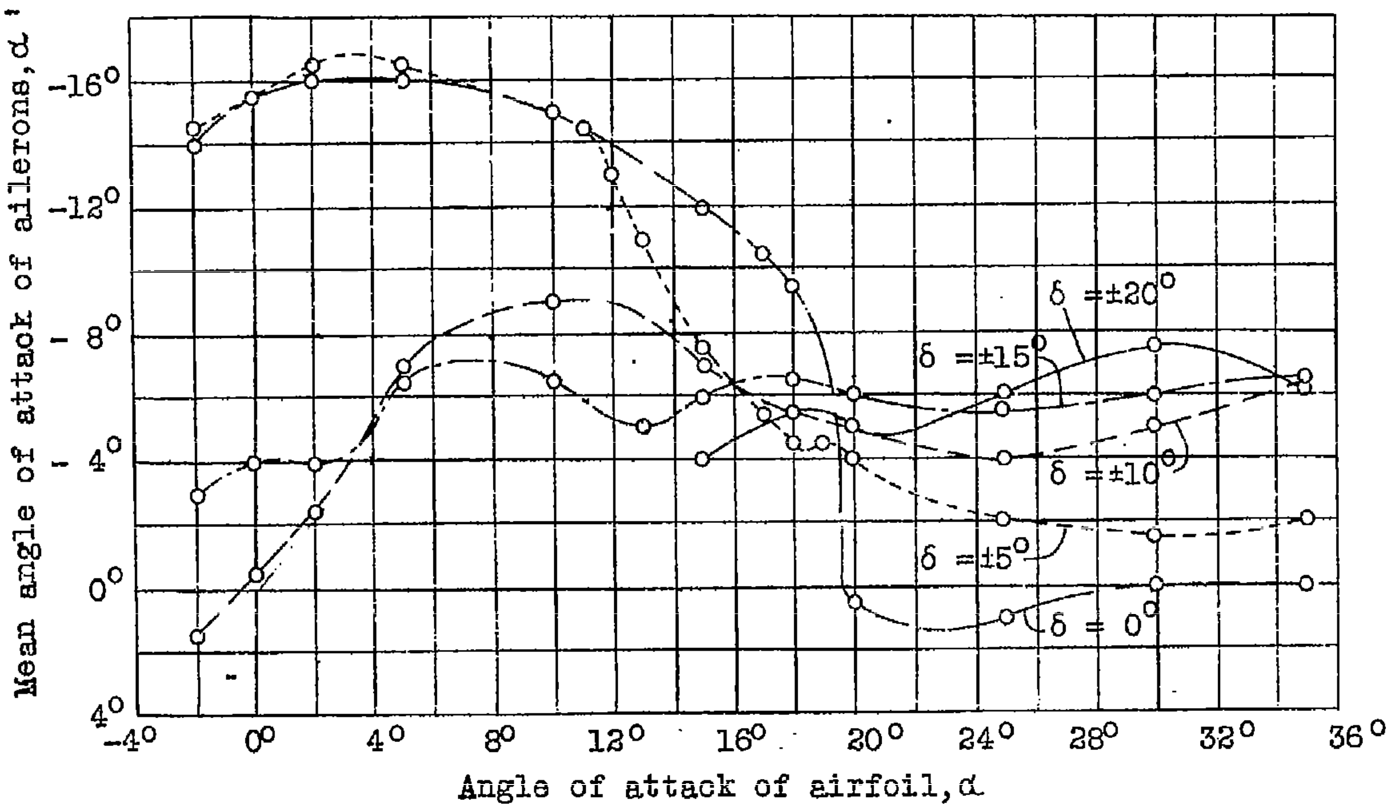


Fig.10 Aileron floating angles vs angle of attack.